Orbits About Asteroid 4769 Castalia

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We have modeled the gravity field near this kilometer-sized Earth-crosser by combining a radar-derived 3D shape model (Hudson & Ostro 1994. Science 263, 940), an assumed uniform density of 3.5 g/cc, and an assumed 4.07-hour rotation about the model's largest moment of inertia. That field can be expressed in closed form as a polyhedron or in terms of standard gravitational harmonic coefficients, is the basis for exploring the stability of orbits near the asteroid and for examining trajectories of impact ejecta. A Jacobi integral is defined for this problem and has been used to generate zero velocity surfaces for the asteroid.

Four synchronous circular orbits, all close to the equatorial plane and separated by roughly 90 degrees in longitude, exist but are unstable. Therefore Castalia exhibits Type II gravitational dynamics about it (Scheeres 1994. "Dynamics about uniformly rotating tri-axial ellipsoids", Icarus, Vol 110, No 1): direct orbits within 3-4 mean radii are unstable and either crash onto the surface or escape. A Jacobi Integral is defined for this problem and has been used to generate zero velocity surfaces for the asteroid. Stable orbits have been found that come within meters of the surface and persist indefinitely under the gravitational attraction of Castalia alone. All these stable orbits are retrograde and close to the equatorial plane. The minimum periapsis of stable orbits increases as the inclination ranges from 180 to 0 degrees, where all direct, near-circular, equatorial orbits within 1.75 km of the asteroid center of mass appear to be unstable and either escape from the asteroid within days or crash on the asteroid surface.

Any rock ejected from an impact event will either return to the surface, enter a stable orbit about the asteroid, or escape. The actual trajectory will depend on surface location and initial speed and direction. For any point, we can calculate the speed v_R, below which ejecta definitely will return to the asteroid, regardless of launch direction; and the speed v_E, above which ejecta will definitely escape, regardless of launch direction. Both v_R and v_E vary over Castalia's surface, as does the interval $v_D = v_E - v_R$. $v_R > 0.08$ m/s everywhere and is as high as 0.4 m/s in some locations. $v_E \leq 1.05$ m/s everywhere and is as low as 0.8 m/s in some locations. $v_D < 0.9$ m/s everywhere. Additional calculations are expected to refine these constraints.

There is no clear transport mechanism between the asteroid's surface and stable, direct, nearly equatorial orbits. Such a mechanism would require either a chaotic path about the asteroid (which would have a low probability of occuring and a high probability of crashing or escaping) or third-body perturbation forces. However, it is possible for some ejecta to be launched into stable orbits. The most likely such orbits are retrograde with respect to the asteroid rotation pole, the ejecta emanating from the vicinity of the longer ends of the asteroid with speeds of ≈ 0.9 m/s. These orbits can come arbitrarily close to the long ends of the asteroid.